Enhancing Tactical Situation Awareness

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Abstract

A framework for tactical situation awareness is presented and used to compare current technology systems with a prototype system supporting tactical situation awareness. The prototype, which is being developed by Australia's Defence Science and Technology Organisation (DSTO) at Edinburgh in its Experimental Command, Control, Communications and Intelligence Technology Environment (EXC3ITE), integrates results from human-in-the-loop (HIL) experiments with an information processing strategy which was reported to the 5th ICCRTS. The HIL work identifies attributes related to tactical electronic intelligence (TacELINT) that are meaningful to tactical commanders. The information processing strategy uses resources accessible in a shared information environment to enrich TacELINT. The prototype aims to demonstrate information products that are meaningful to tactical commanders who don't have TacELINT specialist skills.

1. **Introduction**

The detection and analysis by passive sensing systems of radar signals emitted by military and civilian vessels, aircraft and land-based systems provides an important source of surveillance information that is known as tactical electronic intelligence (TacELINT). Sensor outputs describe the location and parameters of detected emissions. Interpretation can identify the source radar system and its capabilities and, in some cases, associated weapons and their capabilities. For tactical missions this interpretation process can be constrained by prior knowledge.

TacELINT supports tactical commanders in two ways. Firstly, it enhances the surveillance information that is available to a commander, and is one of many inputs into a commander's decision making process. Secondly, TacELINT can provide an alert to potentially serious developments and prompt the commander to take remedial action. These dual roles are encapsulated in a TacELINT Situation Awareness Prototype that is described in this paper.

The prototype is being developed by DSTO in EXC3ITE, and is being designed to deliver TacELINT based information products that are meaningful to tactical commanders who don't have TacELINT specialist skills. As with [Endsley, 1999], the prototype will need careful assessment to evaluate its contribution to situation awareness. Section 2 of this paper presents a framework for assessing tactical situation awareness systems. The performance of current generation TacELINT systems supporting situation awareness is assessed in Section 3, and the performance of the TacELINT Situation Awareness Prototype is assessed in Section 4. These are assessments are compared and discussed in Section 5. A summary is presented in Section 6.

2. **Tactical Situation Awareness Framework**

Situation awareness, as defined by [Endsley, 1995], comprises three elements: the *perception* of entities in the environment, the *comprehension* of their meaning, and the *projection* of their status into the near future. These three elements are mental attributes of a tactical commander and are the desired outcomes of a system supporting tactical situation awareness.

[Lambert, 2001] identifies three inputs to a process to deliver situation awareness to a theatre commander: *technology*, *psychology* and *integration*. Information products are delivered into the commander's environment by *technology* such as sensing systems, databases and graphic visualisation systems. Human *psychology* underlies the commander's observation of and response to stimuli in the environment. *Integration* is the alignment of technology products and psychological processes in the commander's working environment.

These inputs are also relevant to the situation awareness of a tactical commander, as can be seen in the following example of an Armed Reconnaissance Helicopter (ARH). Figure 1 illustrates an ARH commander's physical environment. An audio-visual portal is provided to present information products derived from technology, such as sensors and databases, about entities in the surrounding environment. Other technology is provided to present information about the ARH platform itself, and to enable control of the ARH. Additional stimuli in the commander's

Figure 1. Cockpit Layout of an ARH.

physical environment come from the external world and from the effects of ARH motion. In this example, the inputs to the tactical situation awareness process are: the ability of the underlying *technology* to deliver information products about important entities in the surrounding environment, the *psychology* which drives the commander's observation and response, and *integration*[1] being the design of technology products and the commander's working environment to align with the commander's psychological processes.

The three inputs and three desired outputs of a situation awareness process define a matrix of elements contributing to tactical situation awareness systems, as shown in Figure 2. Measures can be assigned to each element of the matrix. In this paper a four level capability measure is used, namely: *nil*, *weak*, *moderate*, and *strong*, and which is visualised by the intensity of the color of matrix elements. In following sections, this matrix is used to assess the capabilities of current and proposed systems and to suggest future research and development work.

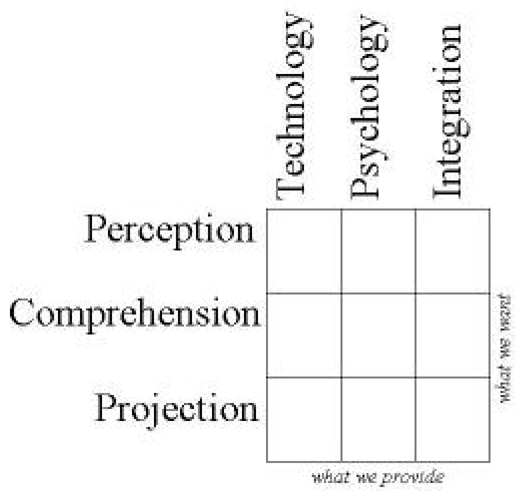

Figure 2. Tactical Situation Awareness: Inputs vs Outputs (after [Lambert, 2001])

3. Extant TacELINT Systems Support for Situation Awareness

3.1 *Technology*

TacELINT systems are able to provide parametric descriptions of detected radar emitters [Wiley 1985], such as the intercept illustrated in the top left of Figure 3 to aid the perception of entities in the environment. As only a course measure of the location is provided by many in-service systems, a bearing line to the radar emitter, the capability to aid *perception* of entities in the environment is only rated as *moderate* in the assessment matrix shown in Figure 3. Radar intercepts can be matched against mission libraries to provide a symbolic description of identity and threat level [Hood and Mason 1987], and can aid the comprehension of perceived entities. However such symbolic descriptions can lack detail or be ambiguous [Mason 1995], and hence the capability to enhance *comprehension* is only rated as *weak*, in the assessment matrix shown in Figure 3. Support for the *projection* of entity status is not provided in current systems and is therefore assessed as *nil* capability in Figure 3.

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[1] Significantly more infrastructure and information resources are available to support a theatre commander than a tactical commander, and so Lambert's a view of integration is broader than that presented in this paper.

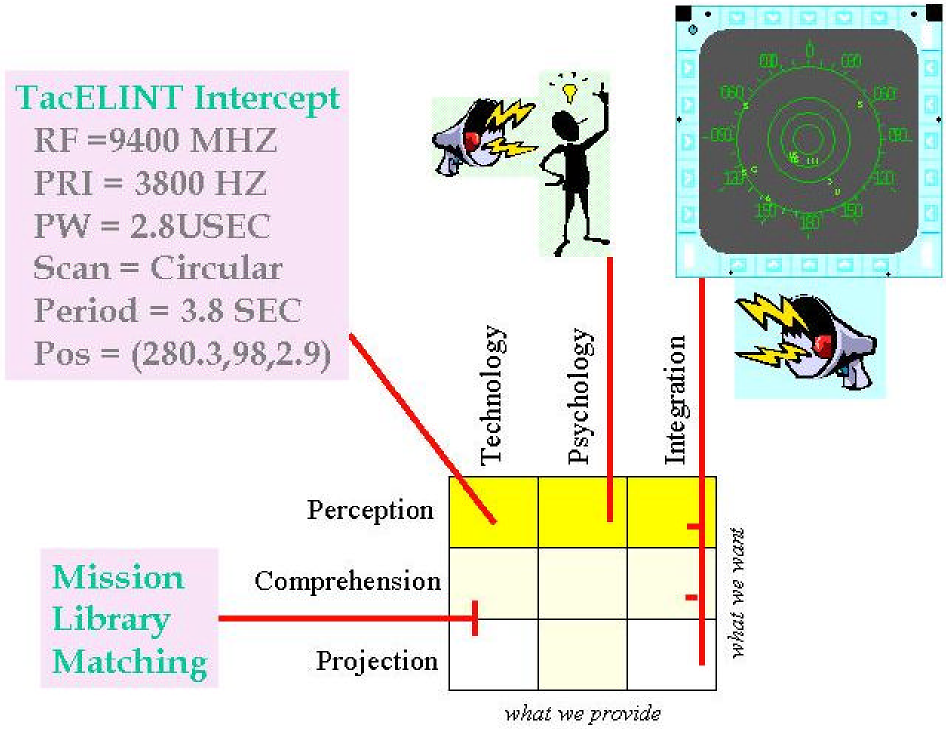

Figure 3. Assessment Matrix for Current TacELINT Situation Awareness Systems

3.2 *Psychology*

Experimental psychology has been concerned with human performance in multitasking activities for many years. Discussion of such research in this paper can only be a simplification of this work. A myriad of experiments, essentially measuring time and accuracy, have come up with a few principles and many exceptions. Papers by [Spivey et al, 2001] and [Yantis, 1998] outline recent investigations into the control of visual attention, such as by audio cues. For example, in a busy and stressful environment (such as an ARH) human attention can be focused by an audio cue to observe and respond to the detection of an important entity in the environment. Thus the capability of *psychology* to aid *perception* of entities in the environment is asessed as *strong*, as shown in Figure 3.

Many cognitive models have been proposed from studies of human comprehension. A generalization from this body of research is that the greater a person's knowledge of a domain, the better their comprehension of events in it. For example, see [Just and Carpenter, 1987] and [Kintsch, 1990]. This poses a problem for tactical situation awareness. Tactical commanders are typically expert in military tactics and are not usually expert in the technologies such as TacELINT, which are provided to support their situation awareness. What psychology does suggest is that the mapping of TacELINT entities into representations similar to the conceptual structures used by tactical commanders for military tactics will aid their comprehension and projection. Because of the generality of this suggestion, the capabilities of *psychology* to aid *comprehension* and *projection* are both assessed as *weak* in Figure 3.

3.3 *Integration*

In current generation systems when an entity of interest is detected it is visualized, and if the entity is sufficiently important, an audio cue is issued. Tactical commanders, with many tasks occupying their attention, are likely to perceive important entities that are detected, and so the *integration* capability for *perception* is assessed as *moderate* as shown in Figure 3.

Technology outputs at the comprehension level in current systems are visualised without any attempt to map them to human conceptual structures. A typical visualisation is shown in the top right of Figure 3 and shows 3 rings to distinguish threat level (with the center ring being the highest threat) and a symbol that may indicate the identity of a threat system. Such a system output allows the tactical commander to distinguish between three classes of threat. While the provision of threat identity does not make any qualities of the threat apparent, it can allow the commander to recall qualities of the threat learnt during training, and so in Figure 3 the *integration* capability for *comprehension* is assessed as *weak*. The *integration* capability for *projection* is assessed as *nil*.

4. **The TacELINT Situation Awareness Prototype**

4.1 *Technology*

Significant advances in sensing technologies, tactical data links and information processing strategies have been made in recent years. The TacELINT Situation Awareness Prototype exploits some of these advances. For example, location measures provided by sensing technologies that are now coming into service are able to provide range as well as bearing in TacELINT data for many types of platforms. Thus in the assessment matrix for the TacELINT Situation Awareness Prototype shown in Figure 4, the *perception* element under *technology* is assessed as *strong.*

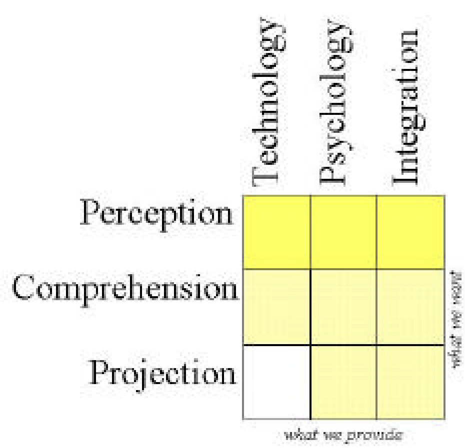

Figure 4. Assessment Matrix for the TacELINT Situation Awareness Prototype

EXC3ITE is a technology demonstrator being developed by DSTO. It is built on a component-based architecture and aims to develop a single, integrated command system supporting all levels of command. Surveillance Data Services have been developed in EXC3ITE that make surveillance products (including TacELINT) available through standard interfaces. Components encapsulating military "business logic" that use surveillance data and information resources are being developed. For example, the EW Information Processing (EWIP) Strategy [Mason, 2000] presented at the 5th ICCRTS exploits resources such as order-of-battle and electronic order-of-battle databases to refine identity estimates of radar emitters. In a TacELINT context this information aids understanding of perceived entities. Thus in the assessment matrix for the TacELINT Situation Awareness Prototype shown in Figure 4 the *technology* element for *comprehension* capability is assessed as *moderate*.

Technology, such as within EXC3ITE, for temporal analysis in tactical applications is very limited. Hence the *technology* element for *projection* is rated *nil* capability in Figure 4. Research activities into technology supporting projection for tactical situation awareness are needed.

4.2 ***Psychology***

Human-in-the-loop (HIL) experiments at DSTO's Air Operations Simulation Centre [Parker, 1998] have measured ARH pilots' performance in recognising and responding to simulated threats. Although based on a small sample, this work shows that visualizations of enriched TacELINT threat information including threat location, detection range, lethality range and geographic terrain, leads to better decision making by pilots that enabled them to successfully complete their missions.

The visualizations provided to ARH pilots in the HIL work can be seen to be elucidating important elements contained within conceptual structures for military tactics brought to the experiment by the ARH pilots. Even though the technology did not explicitly support projection, the ARH pilots were able to use the information provided for projecting future states. For example, pilots were able to determine that it would be safe to fly between two observed threats based on the visualised lethality ranges of the threats.

This HIL work has provided substance for the suggestion made in Section 3.2. However because this work is based on a small sample and only applicable to ARH pilots the *comprehension* and *projection* elements for *psychology* are assessed as *moderate* in Figure 4. The *strong* assessment given to *perception* follows from section 3. Further research into the psychology of TacELINT Situation Awareness systems would strengthen this work.

4.3 ***Integration***

Work within EXC3ITE has extended the EWIP Strategy to yield products whose form is suggested by work mentioned in Section 4.2. These products use information resources including Technical Intelligence (TECHINT) and geographic information to provide specific details of the capabilities and context of detected entities. A typical visualization is shown in Figure 5. This illustration of detection ranges (shown as red shaded areas) and lethality ranges (shown as dark red circles) uses values for "maximum" detection and lethality range from a TECHINT database. The blue areas related to own forces, and the green are mission way-points.

More research and development work on integration will increase the relevance of visualised information to a tactical commander. For example, a more realistic value adding strategy for an ARH would be to compute a detection range for an intercepted threat radar system from values for maximum radiated power for the radar system and the radar cross section value appropriate to the particular ARH. Terrain shielding effects could also be visualised for an ARH in a specific location.

Thus in the TacELINT Situation Awareness Prototype assessment matrix, the *integration* element for *perception* is assessed as *strong*, *comprehension* is assessed as *moderate*, and *projection* is assessed as *moderate*, as shown in Figure 4.

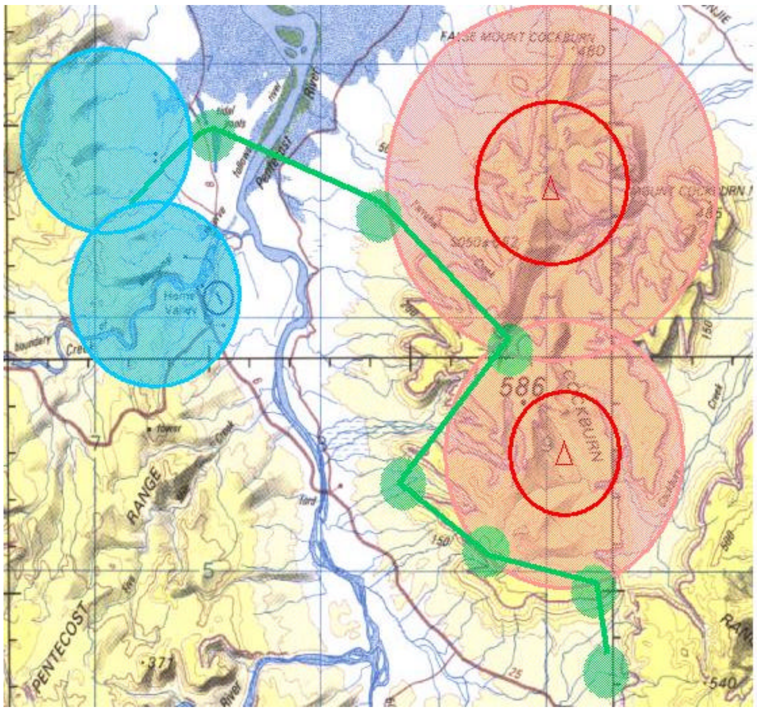

Figure 5. A TacELINT Value-added Product

5. **Discussion**

A comparison of the metrics in Figures 3 and 4 shows that the most significant improvement in the prototype over current systems is in the integration input and the comprehension output. There is also substantial improvement in the projection output.

Factors contributing to these improvements include:

- Sensing systems that provide better location information for detected TacELINT entities
- An understanding of visualizations that are meaningful to tactical commanders
- Development of value-adding strategies that exploit a range of information resources
- Development of infrastructure supporting shared information resources (EXC3ITE).

A facilitator of this work is interdisciplinary collaboration across several organisational units within DSTO. The TacELINT Situation Awareness Prototype is being developed in Electronic Warfare and Radar Division (EWRD) of the Systems Sciences Laboratory (SSL). The Surveillance Data Services within EXC3ITE is being developed within Command and Control Division (CCD) of the Information Sciences Laboratory. The HIL work leveraged in the TacELINT Situation Awareness Prototype was undertaken (in Melbourne) by the Air Operations Division of SSL in collaboration with another work program in EWRD. Interactions with a CCD activity into theatre situation awareness have also influenced the TacELINT prototype.

6. **Summary**

A framework for tactical situation awareness has been presented and used to compare current technology systems with the TacELINT Situation Awareness Prototype. The prototype integrates results from recent HIL experiments that identify TacELINT attributes that are meaningful to tactical commanders with an EWIP strategy exploiting information resources accessible within EXC3ITE. Elements that contributed to the prototype's enhanced capabilities have been identified, and options for further research have been presented.

7. **Acknowledgements**

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